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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1994	Final, August 1990 - October 1992

4. TITLE AND SUBTITLE
Experimental Measurements of the Blast Pressure Profile for 20-mm Perforated Muzzle Brake Designs

5. FUNDING NUMBERS
WO: 612618A-00-001 AJ
PR: 1L16261AH80

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8. PERFORMING ORGANIZATION REPORT NUMBER

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U.S. Army Research Laboratory
ATTN: AMSRL-OP-AP-L
Aberdeen Proving Ground, MD 21005-5066

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ARL-MR-133

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13. ABSTRACT *(Maximum 200 words)*

Pressure measurements were recorded at the Weapons Technology Directorate (WTD) of the Army Research Laboratory to verify predictions of a blast model used at Benet Weapons Laboratory (BWL). An array of 11 piezoelectric gages was placed in a vertical line perpendicular to the gun barrel and positioned at various locations behind the muzzle during the testing of 2 perforated muzzle brakes. The two muzzle brakes were designed and fabricated to fit on a 20-mm Mann barrel. The two brakes were compared to a third device which had no perforations and served as a baseline. The first muzzle brake was a scaled-down version of the EX35 and the second was a special design that had two rows of holes relocated between 7.5 and 9 calibers behind the muzzle ("split brake"). The pressure gage array was used to measure the portion of the blast profile that affected the area behind the gun.

This test was performed in conjunction with the first phase of the test where far field pressure measurements and blast wave shadowgraphs were obtained. This report includes the characteristics of the blast pressure wave for each muzzle device, through pressure profile data and shadowgraphs, as it travels rearward along the gun axis. The results provide quantitative information for precise comparisons to the blast model's predictions.

14. SUBJECT TERMS
20-mm, blast, overpressure, perforated, muzzle brakes

15. NUMBER OF PAGES
19

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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Acknowledgements

This program was made possible thanks to the excellent efforts of Mr. John Carnahan, Mr. William Thompson, and Mr. Brendon Patton, ARL-WTD, in instrumentation setup and operations. The 3-D and contour plots were generated thanks to the efforts of Mr. Kevin Fansler.

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1. Introduction

Pressure measurements were recorded at the Weapons Technology Directorate (WTD) of the U.S. Army Research Laboratory (ARL) to verify predictions of a blast model developed at Benet Weapons Laboratory (BWL). [1] An array of 11 piezoelectric gages was placed in a vertical line perpendicular to a 20-mm gun barrel and positioned at various locations behind the muzzle during the testing of 2 perforated muzzle brakes. The two muzzle brakes were chosen for their differences in pressure distribution behind the muzzle. The pressure gage array was used to measure the portion of the blast profile that affected the area behind the gun. The 11 gages were set at specific increments from the barrel's exterior wall.

The test was the continuation of a joint effort between BWL and WTD to study the effects of various perforated muzzle brakes for the 20-mm, 105-mm, and the 120-mm guns. In particular, the test was performed in conjunction with the first phase of another test where far field pressure measurements and blast wave shadowgraphs were taken.[2]

This report includes the blast overpressure data in comparison with the shadowgraphs that were taken at or about the same locations. The results from the blast profile test were useful in providing quantitative information for precise comparisons to BWL's blast model.[1] The experimental analysis will contribute to the improvement of the blast code resulting in a more precise computational analysis of future designs.

2. Test Setup

The test was performed at WTD's indoor Aerodynamics Range. A schematic drawing of the test setup is shown in Figure 1. The firings and measurements were performed in an anechoic chamber to eliminate reflecting blast waves that strike the range walls near the gun, as seen in the photograph of the test setup (Figure 2).

Two muzzle brakes (devices 5 and 7) were tested and compared to a baseline device (device 1) that had no perforations (Figure 3). Each device was designed and fabricated to fit on a 20-mm Mann barrel that was threaded at the muzzle. Each device had the same dimensions (28 cm in length) aside from their individual hole patterns. Device 5 is the scaled-down version of the 105-mm EX35 perforated muzzle brake design that is being supplied as government-furnished equipment for the Armored Gun System, currently in full development. Device 7 was tested for the 105-mm gun and is of special interest because of its unique "split brake" design (two rows of holes are spaced upstream from the other perforations). The ammunition used for this test was Cartridge, 20-mm, TP, M55A2.

An array of piezoelectric gages was mounted in a steel block that was fabricated into a wedge shape (see Figure 4). The wedge was used to assure that the flow of the blast wave was not obstructed or interfered with before reaching the gages. The gages were fixed in the

[1] Carofano, G.C., "Blast Field Contouring Using Upstream Venting," The Fourth International Symposium on Computational Fluid Dynamics, U. of California-Davis, Davis, California, September 9-12, 1991, p138-143, Benet Laboratories Technical Report in publication.

[2] Savick, D.S., "Test Comparison for 20-mm Perforated Muzzle Brakes," ARL-MR-31, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD 21005-5066, February 1993.

wedge to measure static pressure with their measuring surfaces positioned flush to the surface of the wedge block. The array of gages was adjustable to incremental distances behind the muzzle for the test requirements. The array consisted of 11 gages that were positioned in a line perpendicular to the gun barrel. The first six gages were positioned at increments of 12.7 mm (0.5 in) from the barrel exterior while the remaining five were at increments of 25.4 mm (1 in). The distance from the barrel centerline to the first gage was 40 mm (1.6 in). Pressure was measured a total vertical distance of approximately 20 cm from the barrel surface. Nicolet oscilloscopes recorded and stored the required data.

3. Procedure

Pressure data were recorded for the three muzzle devices at various distances behind the muzzle. The pressure gage array was initially positioned over the original muzzle (muzzle location when devices are absent, as seen in Figure 5) and repositioned at predetermined locations behind the original muzzle after each device had been tested at that location. Two to four rounds were fired through each device to establish a valid sample at each location. The pressure was recorded at the following locations behind the muzzle: 0, 5, 10, 15, 20, 25, 30, 40, and 50 cm. The data were reduced and peak overpressure was analyzed and compared.

4. Analysis

4.1 Blast Pressure and Shadowgraphs. Figures 6-8 represent 3-D plots showing the peak overpressures of the three muzzle devices at specified locations along the gun (Note: Figures 7 and 8 are plotted using a larger pressure scale). The vertical distance in these plots and the plots to follow are defined as the measured distance from the barrel exterior wall (28 mm from the barrel centerline). Figures 9-11 represent the pressure contour plots of the three muzzle devices. From these figures, the strength of the peak pressure can be studied as the blast wave travels behind the muzzle and away from the barrel. The following is observed: The pressure values for device 1 are smaller than the pressure values from devices 5 and 7. Devices 5 and 7 produce higher pressures behind the gun than device 1 due to the gases emanating from the side ports.

Figures 12 and 13 show a 3-D plot and contour plot of the ratio of pressures for device 5 and device 7. When the peak overpressures are measured behind the muzzle from 10 to 50 cm, device 7 produces weaker pressures than device 5. Savick[2] found that the interaction between the two forming blast waves near device 7 weaken their overall strength as they traveled rearward of the muzzle. This interaction can be observed in the shadowgraph of the blast waves of device 7 taken after the projectile exited the device (Figure 14). The blast wave of the front vents that travels rearward is intercepted by the blast wave of the rear vents that is traveling forward.

In the region from 0 to 10 cm horizontally and 0 to 10 cm vertically, device 7 has a stronger peak overpressure than device 5. This is due to the probes being almost directly above the rear vents of device 7. In this position, the gages measure pressure that trav-

els outwardly as well as towards the rear. As the probes are positioned further rearward (10 cm and beyond), the gages measured only the part of the blast wave that traveled towards the rear of the gun. In the region from 0 to 10 cm horizontally and 10 to 20 cm vertically, device 5 had a stronger peak overpressure than device 7. From this observation, it is found that the blast pressure for device 7 is greater than device 5 only inside a 10-cm radius.

To demonstrate the difference in blast waves of devices 5 and 7, shadowgraphs of each blast wave were taken separately at approximately the same location along the gun barrel. Figure 15 shows the blast wave for device 5 and Figure 16 shows the blast wave from device 7. The blast wave from device 5 is thicker and more defined in strength than the blast wave from device 7.

4.2 Blast Overpressure and Blast Code Analysis. The experimental results were compared to analytical data produced by Carofano's blast code.[1] The code calculated the peak overpressure of each pressure probe for four different locations behind the muzzle. The locations include 0, 15, 30, and 50 cm. Figures 17-19 show the comparison of the calculated data with the corresponding experimental data.

The predictions seem to be more accurate for the locations that are further away from the muzzle (i.e., 30 and 50 cm) for all three devices. The pressures that were measured at or near the muzzle are a result of a more complex flow field than could be predicted. Device 7 (Figure 19) is especially complicated due to the rear set of the holes of the "split brake" being much closer to the probes than the other devices. The pressures at the 30-cm and 50-cm positions for device 7 were also difficult to predict. It appears that the interaction between the two blast waves from the "split brake" have a larger effect on each other than could be predicted. The 30 and 50 cm predictions agree better with the experimental data at the probes 6 and 7 region (3-4 cm, vertically).

5. Summary and Conclusions

1. Overpressures for device 1 were consistently lower in comparison to devices 5 and 7.

2. Device 7 had lower blast overpressures than device 5 for distances 10-50 cm behind the muzzle.

3. The two vent areas of device 7 formed blast waves that lessened the rearward overpressure.

4. The shadowgraph for device 5 showed a thicker and stronger looking blast wave than the shadowgraph of the blast wave from device 7. The pressure results confirmed the shadowgraph results.

5. The blast code provided better predictions for each device at locations 30 cm and beyond the rear of the muzzle.

6. The predictions made closer to the muzzle could not account for all the complexities of that flow field region.

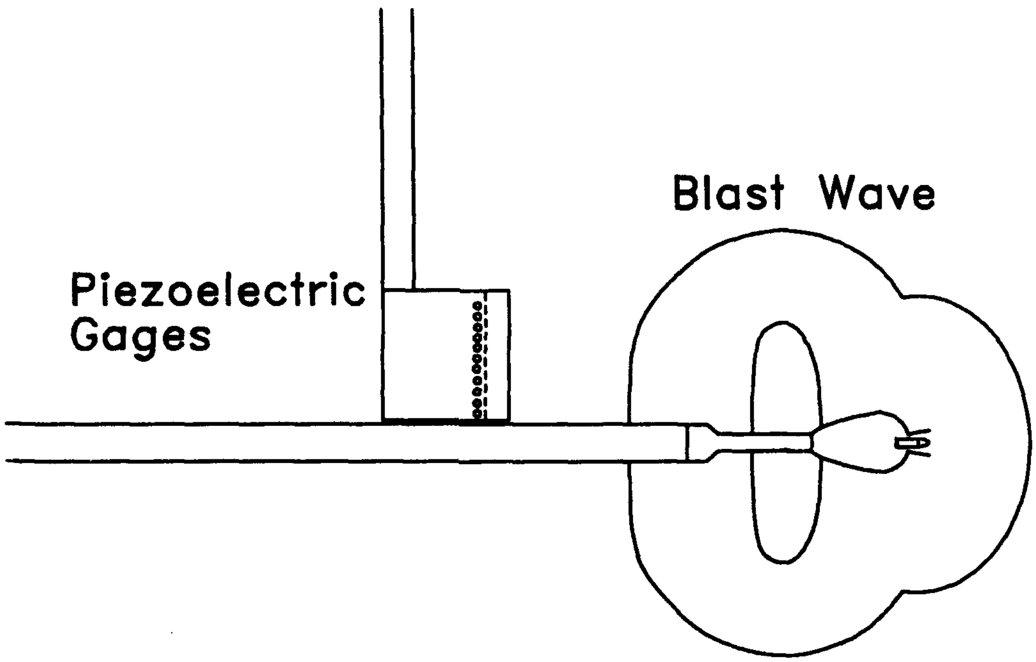

Figure 1. Schematic Drawing of Test Setup

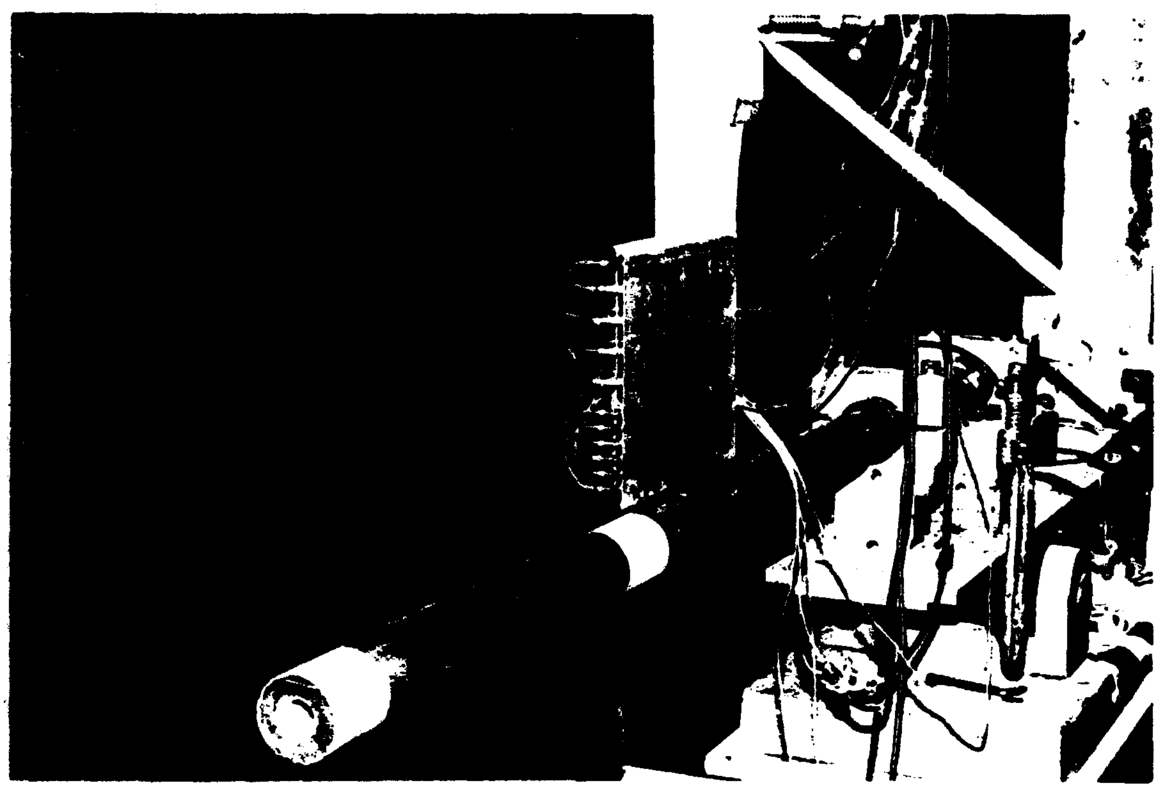

Figure 2. Photograph of Test Setup

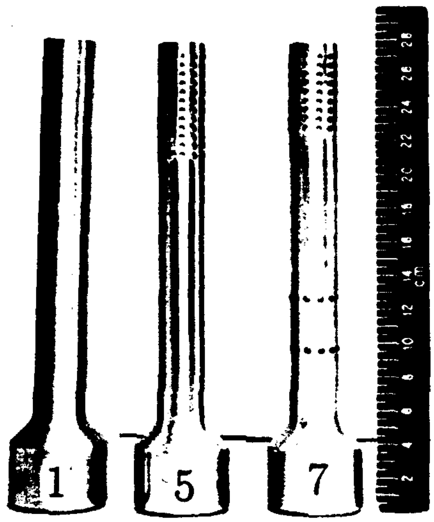

Figure 3. 20-mm Perforated Muzzle Brake Devices

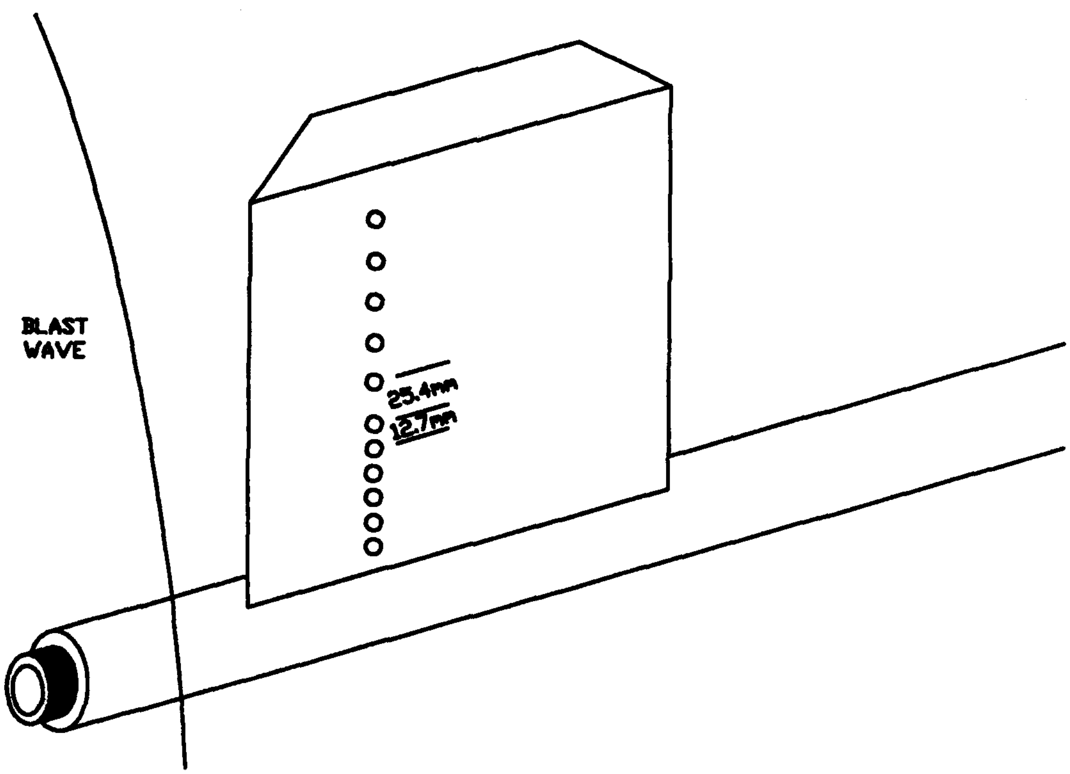

Figure 4. Piezoelectric Gages (Probes) Mounted in Steel Wedge.

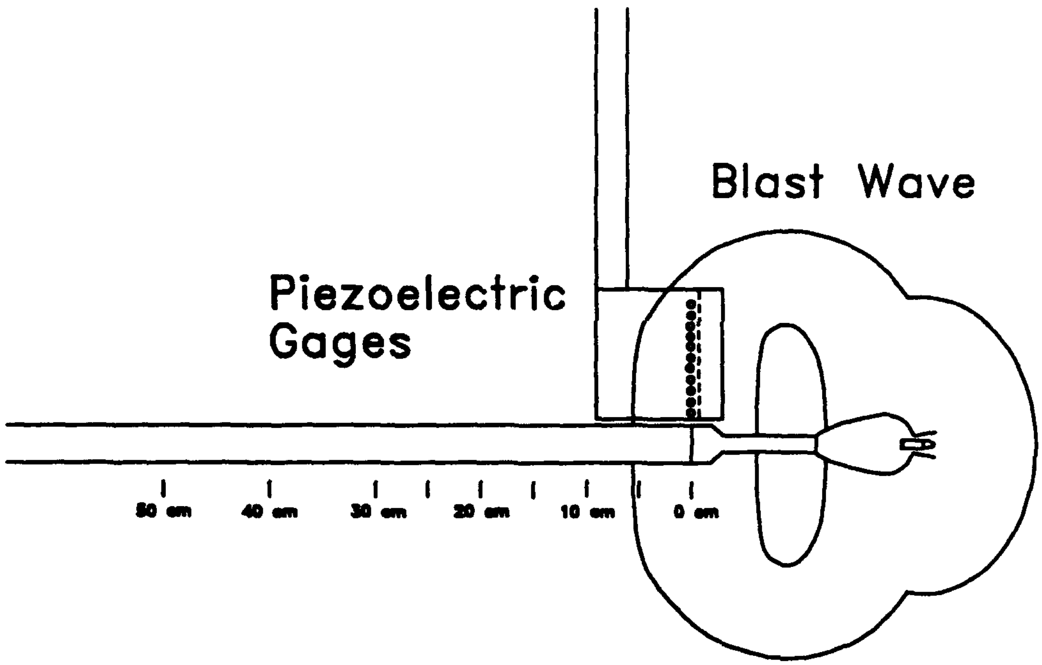

Figure 5. Schematic Drawing of Locations for Recording Overpressure.

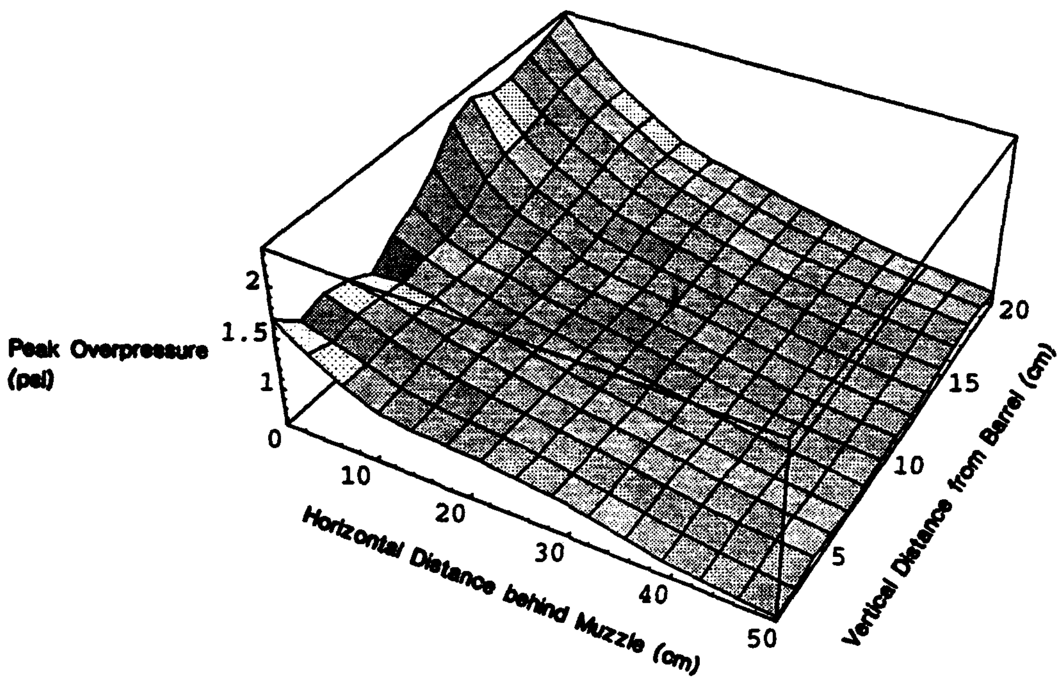

Figure 6. 3-D Plot of Peak Overpressure for Device 1.

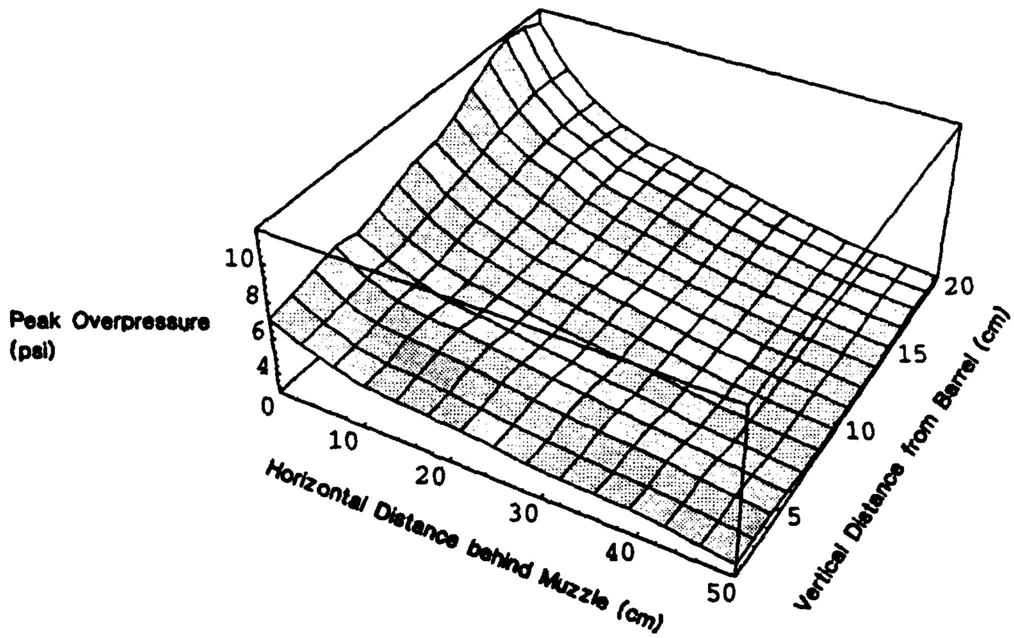

Figure 7. 3-D Plot of Peak Overpressure for Device 5.

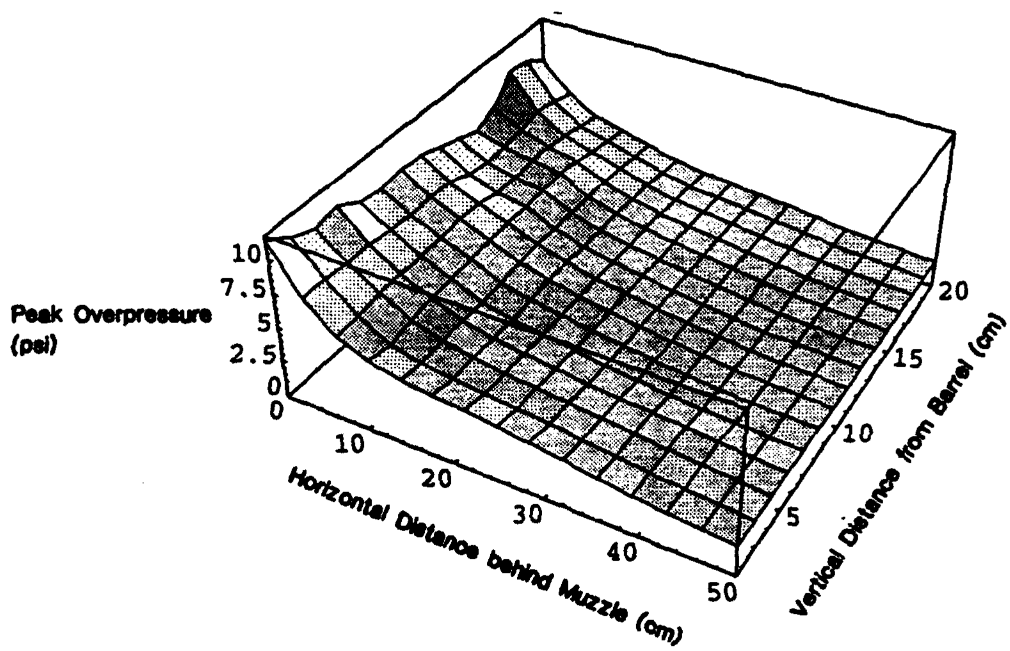

Figure 8. 3-D Plot of Peak Overpressure for Device 7.

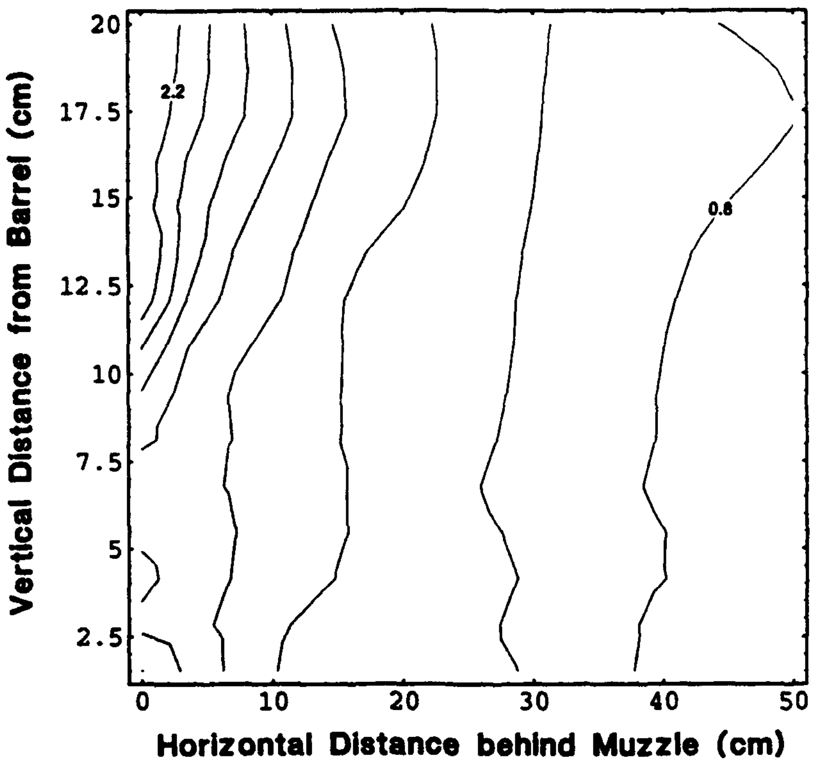

Figure 9. Contour Plot of Peak Overpressure for Device 1. Peak Overpressure Contours Ranged from 2.2 to 0.8 psi in Increments of 0.2 psi.

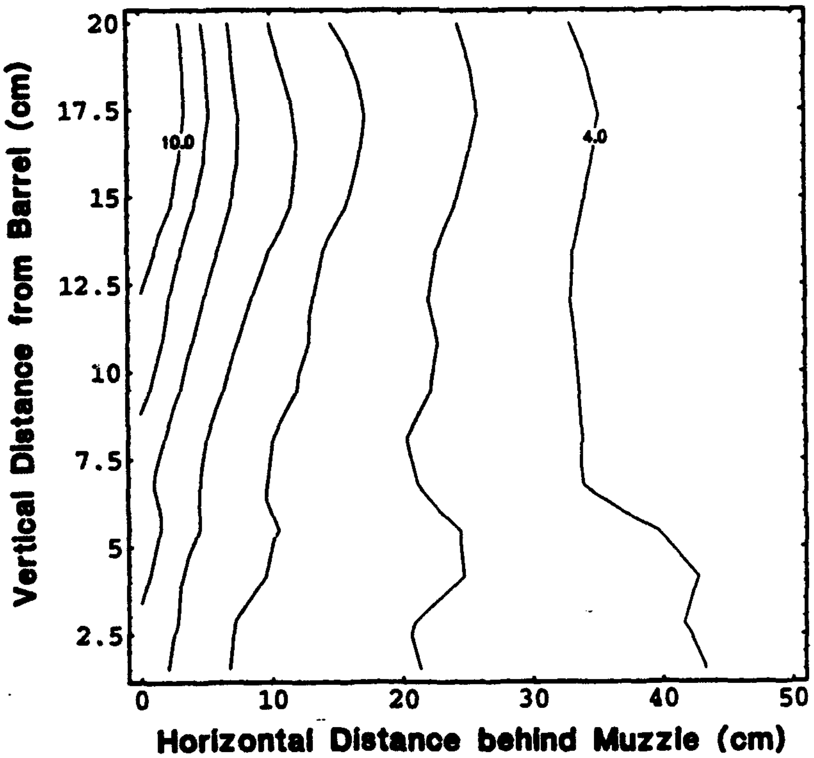

Figure 10. Contour Plot of Peak Overpressure for Device 5. Peak Overpressure Contours Ranged from 10.0 to 4.0 psi in Increments of 1.0 psi.

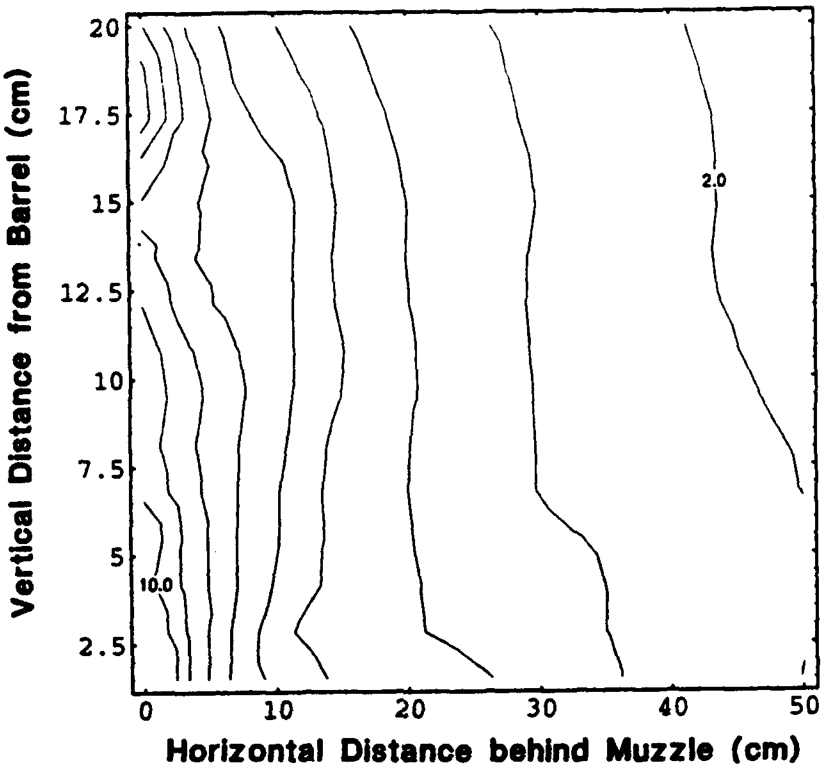

Figure 11. Contour Plot of Peak Overpressure for Device 7. Peak Overpressure Contours Ranged from 10.0 to 2.0 psi in Increments of 1.0 psi.

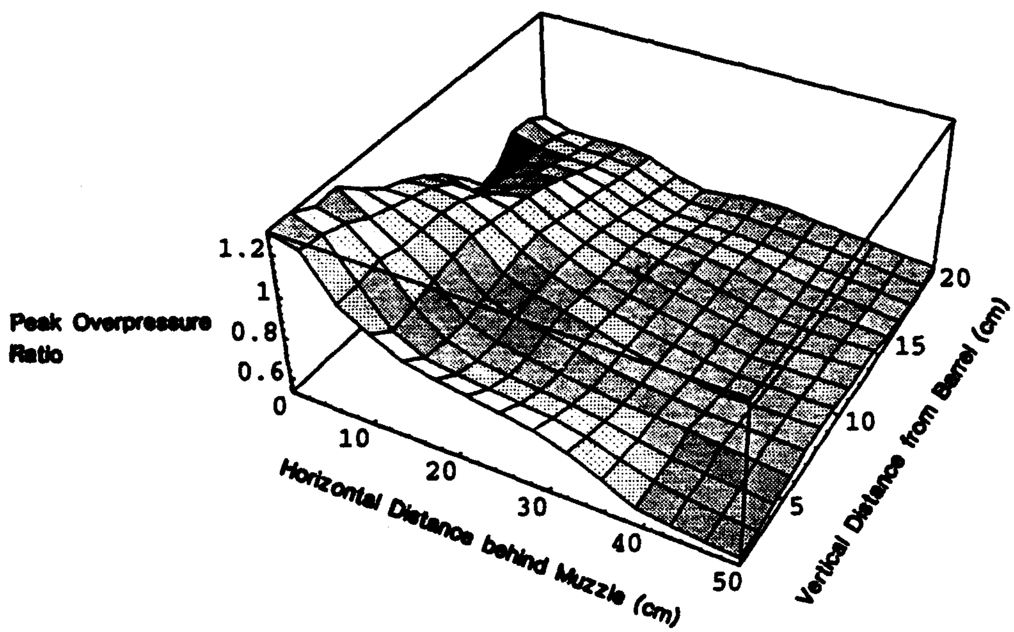

Figure 12. 3-D Plot of Peak Overpressure Ratio - Device 7/Device 5.

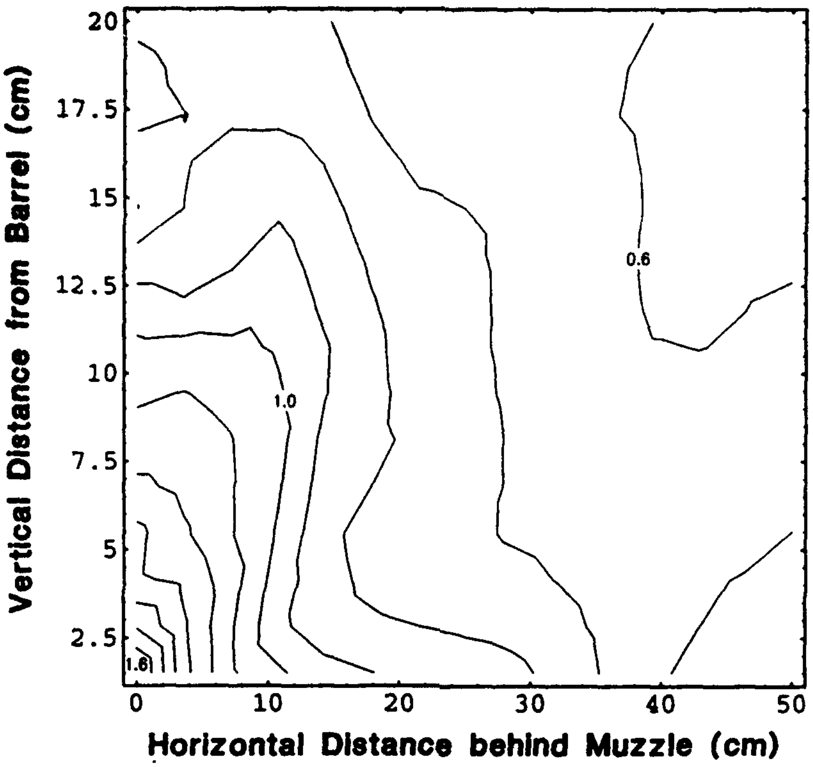

Figure 13. Contour Plot of Peak Overpressure Ratio - Device 7/Device 5. Pressure Ratios Ranged from 1.6 to 0.6 in Increments of 0.1.

Figure 14. Shadowgraph of the Blast Waves Exiting the Vents of Device 7.

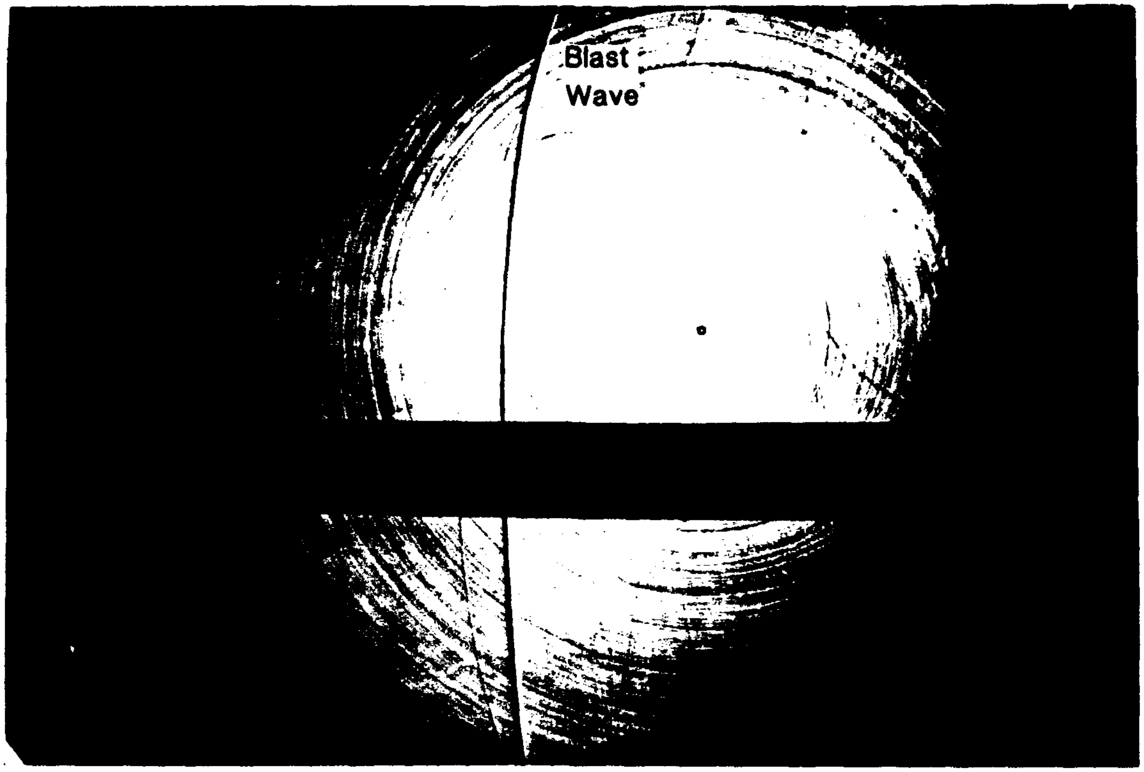

Figure 15. Shadowgraph of the Blast Wave of Device 5 at Approximately 50 cm.

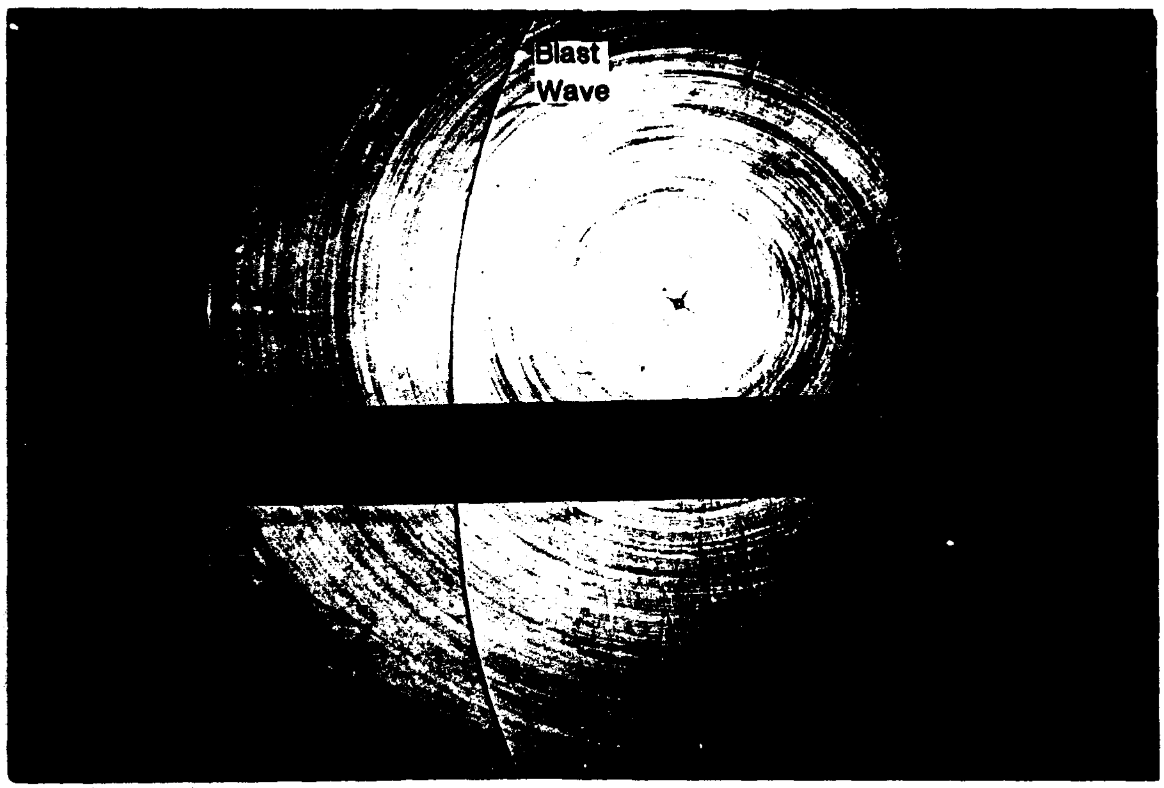

Figure 16. Shadowgraph of the Blast Wave of Device 7 at Approximately 50 cm.

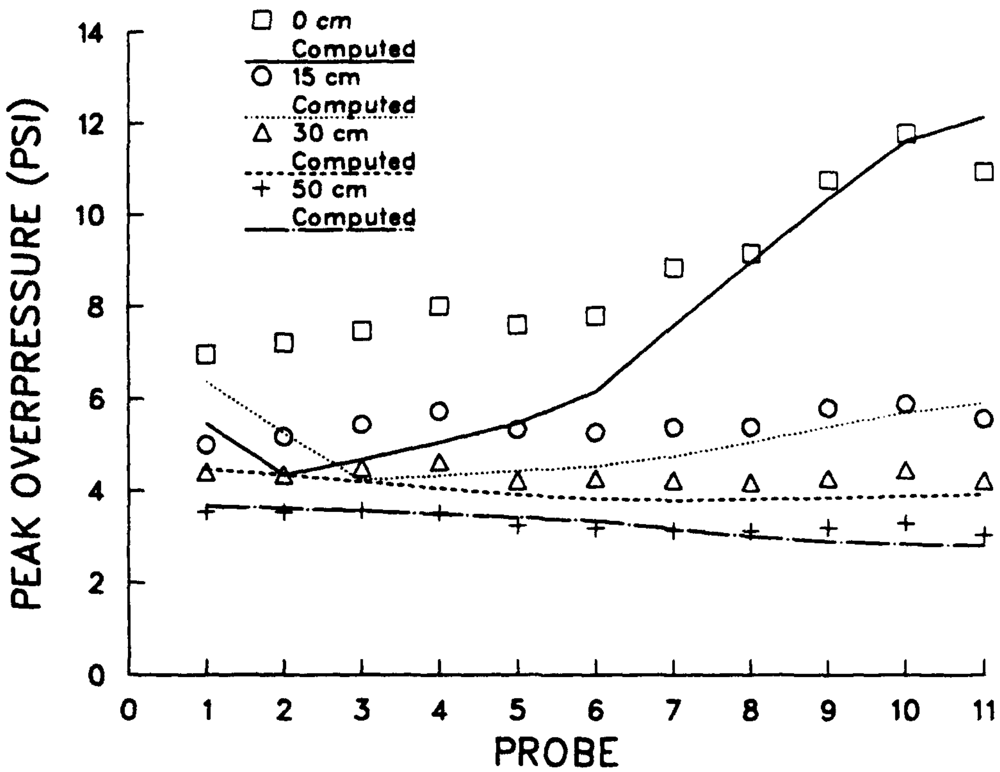

Figure 17. Computed and Empirical Peak Overpressure Comparisons for Device 1.

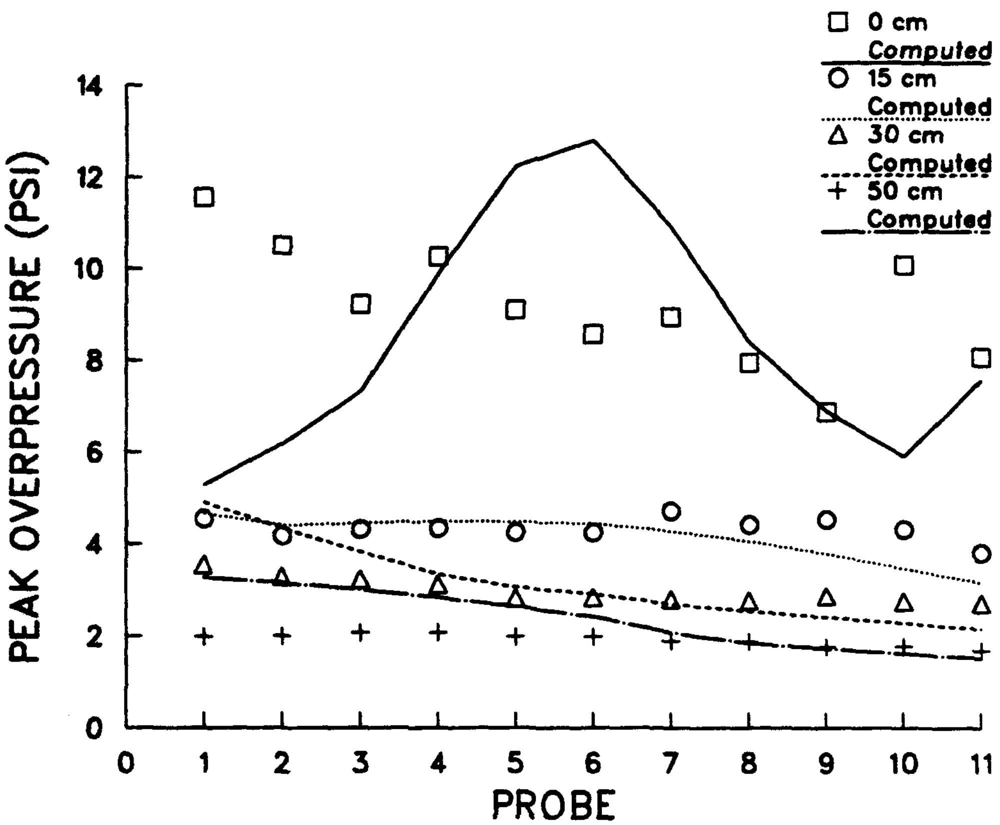

Figure 18. Computed and Empirical Peak Overpressure Comparisons for Device 5.

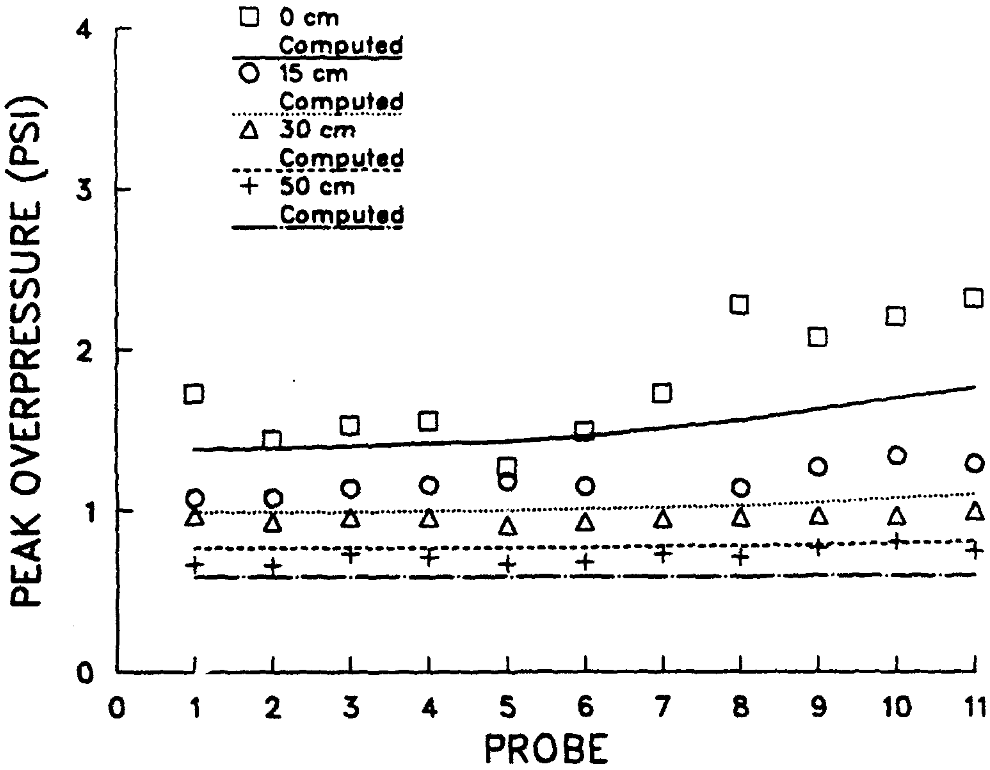

Figure 19. Computed and Empirical Peak Overpressure Comparisons for Device 7.

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